



# Process Modeling and In-Situ Sensor Feedback Based Adaptive Control of Molecular Beam Epitaxy and Ion-Assisted Reactive Etching of Advanced



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Semiconductor Structures

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URL: [www.usc.edu/dept/materials\\_science/CIM](http://www.usc.edu/dept/materials_science/CIM)

## Control of Thermal $\text{Cl}_2$ Etching of GaAs

### Nonlinear Model:

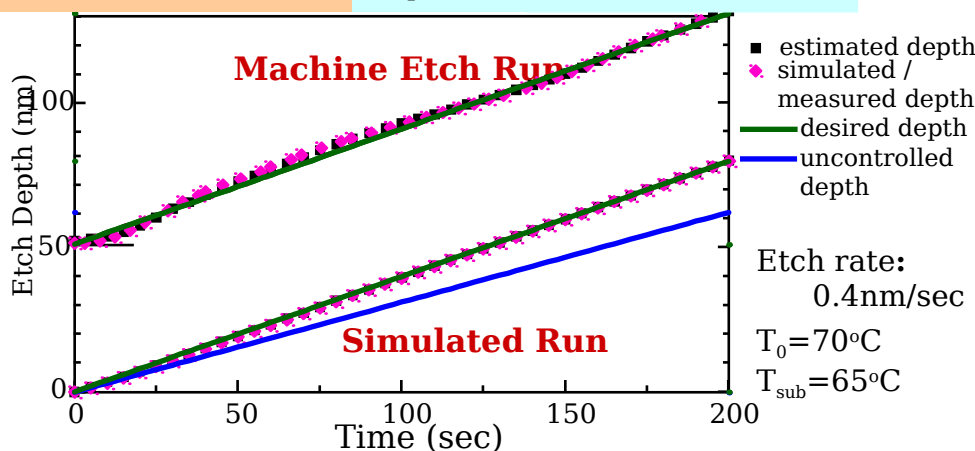
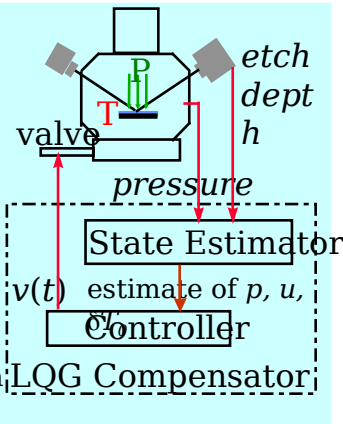
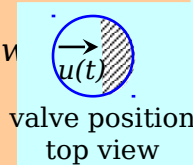
$$\dot{d}(t) = A \exp\left(\frac{-\varepsilon}{R(T_0 + \delta T_0)}\right) p(t)^n + w_{11}$$

$$\dot{p}(t) = \alpha I_0 \frac{S(u(t))}{V_0} p(t) + w_{12}(t)$$

$$\ddot{u}(t) + \beta \dot{b}_0 u(t) + \alpha_0 u(t) =$$

$$y_0 v(t)$$

$$y(t) = (d(t), p(t)) + v$$



### Technical Approach

- Spectroscopic Ellipsometry (SE) as the in-situ material property sensor.
- Physical model of actuator (gate valve) dynamics and chamber pressure response.
- Adaptive Linear Quadratic Gaussian (LQG) compensator

### Objectives

1. Spectroscopic Ellipsometry (SE) Based Supervisory Control of Etching of Dielectrics / Semiconductors.
2. Reflection High-Energy Electron Diffraction (RHEED) Based Run-to-Run and Machine-to-Machine Supervisory Control of Molecular Beam Epitaxial (MBE) Growth Conditions.
3. Development and Validation of Paradigms and Parallel Molecular Dynamics Algorithms for Multi-Million Atom Simulations of Stresses in Nanopixels and MBE Process.

Development of in-situ sensor based adaptive real-time process control provides the enabling technology for the manufacture of nanoscale (<100nm) device arrays of critical importance to DoD needs in electronics, imaging, etc.

### Accomplishments (Third Yr. '97-98)

- Demonstrated a process model and in-situ SE sensor feedback based adaptive real-time control of semiconductor etching, accounting for the actuator (gate valve) dynamics. (See illustration)
- Developed and successfully tested softwares for automatic MCTF identification for MBE growth reproducibility based on static RHEED sensor data.
- Implemented 10 million atom simulations of atomically-resolved stresses in Si/Si<sub>3</sub>N<sub>4</sub> nanopixels, crack propagation in the Si<sub>3</sub>N<sub>4</sub> overlayer, and